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(54) Imidazolium salts and the use of these ionic liquids as a solvent and as a catalyst

(57) New 1,2,3- or 1,2,3,4- or 1,2,3,4,5- substituted imidazolium salts and their uses as solvent in catalyzed organic reactions, as well as compositions containing them and a transition metal compound. They can be used in the following reactions : the telomerisation of conjugated dienes, the dimerisation of olefins, the oligomerisation of olefins, the polymerization of olefins, the alkylation of olefins, the hydrogenation of olefins, the olefin metathesis, the hydroformylation of olefins, the ring-closing metathesis of olefins, the ring-opening metathesis polymerisation of olefins, the symmetric or asymmetric

epoxidation of olefins (including heteroatom substituted olefins) and the cyclopropanation of olefins, the condensation reaction, the hydrogenation reaction, the isomerization reaction, the Suzuki cross-coupling reactions, the amination reaction, the partial oxidation of alkanes, the kinetic resolution of racemic mixtures, the hydrogenation of imines, the hydrogenation of ketones, the transfer hydrogenation and the hydroxylation of aromatic organic compounds.

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Description

[0001] The present invention is related to the use of imidazolium salts as solvents and to new imidazolium salts and compositions containing the same. In particular the imidazolium salts may be used as a solvent in organic reactions, in particular in catalytic reactions such as two-phase catalytic conversions of olefins.

[0002] Low melting salts which are liquid at room temperature up to 200 °C can be used as liquid media in many organic reactions. Usually these salts are referred to as "ionic liquids". Frequently the ionic liquids have two functions in that they not only serve as a solvent for the reaction but also as a catalyst or catalyst component.

[0003] In other cases the ionic liquids serve only as a solvent for the catalyst, that is the ionic liquid is not miscible with the reactants or the reaction product. In this case the reaction occurs at the phase boundary of the catalyst solution and the reaction products form a separate phase. This process using two separate liquid phases is suitable, if the reaction product must be quickly removed from the reaction mixture in order to avoid subsequent reactions. Moreover the catalyst and the reaction product can be separated under gentle conditions.

[0004] Further advantages of ionic liquids are their chemical and thermal stability which allows their application in many processes. Further they are not volatile and therefore they are safer for chemical industry personnel and the general public and environment.

[0005] Among the ionic liquids known as solvents in the art imidazolium salts have attracted attention (for a recent review, see for an example "Ionic liquids" of J.D. Holbrey, K.R. Seddon in *Clean Products and Processes* 1 (1999) 223-236).

[0006] For example CHEMTECH, September 1995, pages 26 and the following pages discloses a mixture of 1,3-di-alkylimidazolium chloride, in particular 1-n-butyl-3-methyl-imidazolium chloride (abbreviated as BMI⁺Cl⁻) and aluminium chloride and/or ethyl aluminium chloride as non-aqueous solvent for the catalyst.

[0007] Am. Chem. Soc., Div. Pet. Chem. (1992), 37, pages 370 etc. discloses the dimerization of propene in the presence of a solution of NiCl₂(PR₃)₂ (R=i-C₃H₇) in a mixture of BMI⁺Cl⁻ and AlCl₃ as ionic liquid.

[0008] EP-A-0,776,880 (corresponding to US 5,874,638) discloses for example a process for the hydroformylation of olefinic compounds in the presence of an ionic liquid.

[0009] Angew. Chem. 1995, 107 n° 23/24, pages 2941 etc. also disclose the hydroformylation using liquid 1,3-di-alkylimidazolium salts.

[0010] EP-A-0,404,179 and EP-A-0,398,358 disclose 1,2,3-trialkylimidazolium halides and their mixtures with aluminium halides as electrolytes.

[0011] Not prior published German patent application n° 19919494.7 (corresponding to international patent application n° PCT/EP00/03499) discloses non aqueous ionic ligand liquids of the formula (Q_i)_cA⁻, wherein Q_i⁺ is a singly charged ammonium cation, optionally substituted with organic group(s), or the equivalent of a multiply charged ammonium cation and A⁻ is an anion of a sulfonated or carboxylated triester of phosphorous acid and c is an integer of at least one. Among the ammonium cations there are also mentioned 1,2,3,4,5-pentamethylimidazolium, 1,2,3,5-tetramethyl-4H-imidazolium, 1,2,3,4-tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium.

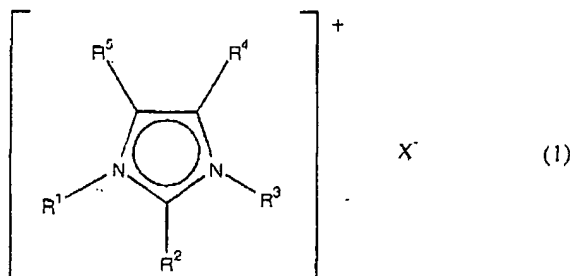
[0012] J. Dupont et al. (*Organometallics* 1998, 17, 815-819) disclose a catalytic process of hydrodimerization of 1,3-butadiene by palladium compounds dissolved in ionic liquids. As palladium catalyst compounds [(η³-C₄H₇)Pd-μ-Cl]₂, [(η³-C₄H₇)Pd(1,5-cyclooctadiene)] [BF₄]⁻ and palladium acetate have been used which are not to be completely soluble and stable in the ionic liquids 1-n-butyl-methylimidazolium tetrafluoroborate (BMI⁺.BF₄⁻) and 1-n-butyl-methylimidazolium hexafluorophosphate (BMI⁺.PF₆⁻) at room temperature. At the end of the performed hydrodimerization reactions however metallic palladium was detected thus limiting the reutilization of the catalytic system. This has been attributed to the instability of these catalysts to water. The formation of metallic palladium could be suppressed by the use of a new catalyst precursor (BMI)₂PdCl₄ which has been obtained by reacting PdCl₂ with a 2 molar excess of 1-n-butyl-3-methylimidazolium chloride in acetonitrile at reflux temperature. However even for this stable catalyst conversions reported were low.

[0013] In an attempt to use conventional palladium phosphine catalysts in the presence of ionic liquids such as the above mentioned 1-n-butyl-methylimidazolium tetrafluoroborate (BMI⁺.BF₄⁻) or 1-ethyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide (EMI⁺.TF₂N⁻) for the telomerization of butadiene for example with methanol, the present inventors found surprisingly that the conventional palladium phosphine catalyst system in the presence of ionic 1,3-di-alkylimidazolium liquids in contrast to the above mentioned catalyst compounds like [(η³-C₄H₇)Pd-μ-Cl]₂, [(η³-C₄H₇)Pd(1,5-cyclooctadiene)] [BF₄]⁻ or palladium acetate shows almost no reactivity, and thus was not available for a telomerization process in the presence of the ionic liquid.

[0014] Therefore, the object underlying the present invention was to find new stable imidazolium salts which can be used, in particular, in catalytic processes without having a detrimental effect on the catalytic process. Surprisingly they found that imidazolium salts wherein at least the 1,2 and 3-position of the imidazolium heterocycle is substituted have a less detrimental effect when used as a solvent and therefore could be used advantageously as a solvent in catalyzed reactions, for example in the catalytic telomerization of conjugated dienes.

[0015] Thus in accordance with the present invention there is provided a new use of 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium-, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with sulfonated or carboxylated triesters of phosphorous acid as anion, as solvent.

[0016] Preferred 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts are those of the following formula (I)



wherein R¹ and R³ are the same or different and are each selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms, and a tri(C1-C10) alkylsilyl group,

R² is selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms and a halogen atom; more preferably R² is an alkyl group or an aryl group, R⁴ and R⁵ are the same or different and are each selected from the group consisting of hydrogen, a chiral or achiral alkyl group having up to 10, preferably up to 6 carbon atoms, a chiral or achiral aryl group of 6 to 10 carbon atoms, a chiral or achiral tri(C1-C10)alkylsilyl group, and a halogen atom; more preferably R⁴ and R⁵ are hydrogen, an alkyl group, an aryl group, or a tri(C1-C10)alkylsilyl group, still more preferably hydrogen, and X⁻ represents an anion.

[0017] The aforementioned alkyl group having up to 10 carbon atoms (sometimes abbreviated as "C1-C10"), preferably up to 6 carbon atoms (sometimes abbreviated as "C1-C6") in the definitions of R¹ to R⁵ includes linear or branched alkyl groups, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, iso-butyl, sec. butyl, ter.-butyl, n-pentyl, isopentyl, neopentyl, n-hexyl, n-heptyl, n-octyl, n-nonyl and n-decyl. Preferred are alkyl groups with up to 6 carbon atoms.

[0018] The aforementioned aryl group of 6 to 10 carbon atoms includes for example phenyl or naphthyl.

[0019] With respect to the above mentioned (C1-C6)alkyl moiety of the tri(C1-C6)alkylsilyl group it is referred to the definition of the C1-C6 alkyl groups for R¹ to R⁵.

[0020] Halogen atoms in the above definition include for example fluorine, chlorine, and bromine.

[0021] Preferred anions X⁻ in the above mentioned formula (I) are preferably selected from anions of the group consisting of fluoride, chloride, bromide, iodide, hexafluorophosphate, hexafluoroantimonate, hexafluoroarsenate, fluorosulfonate, tetrafluoroborate, bis-perfluoro(C1-C10)alkylsulfonyl amides, perfluoro(C1-C10)alkyl sulfonates, dichlorocuprate, tetrachloroborate, tetrachloroaluminate, heptachlorodialuminate (Al₂Cl₇⁻), trichlorozincate, and anions of sulfonated or carboxylated (alkyl and/or aryl)- phosphines or phosphites.

[0022] With respect to the aforementioned (C1-C10)alkyl moiety in the definitions "bis-perfluoro(C1-C10)alkylsulfonyl amide" and "Perfluoro(C1-C10)alkyl sulfonate" it is referred to the definition of the C1-C10 alkyl groups for R¹ to R⁵ above.

[0023] Particular preferred solvents are 1,2,3-tri(C1-C10)alkyl-imidazolium salts. With respect to the aforementioned (C1-C10)alkyl moiety in the "1,2,3-tri(C1-C10)alkyl-imidazolium salts" it is referred to the definition of the C1-C10 alkyl groups for R¹ to R⁵ above.

[0024] (Alkyl and/or aryl)-phosphines or phosphites in the definition of the anions of sulfonated or carboxylated (alkyl and/or aryl)- phosphines or phosphites include all kinds of anions of alkyl and aryl phosphines or phosphites like monodentate or bidentate phosphines or phosphites having up to 36 carbon atoms in the hydrocarbon moieties, like alkyl, aryl, arylalkyl etc.

[0025] Particular preferred a 1-n-butyl-2,3-dimethylimidazolium salt is used as a solvent.

[0026] Preferably the above substituted imidazolium salts are used as a solvent in organic reactions, in particular in the presence of a catalyst, wherein the catalyst may comprise a transition metal compound, in particular from the group

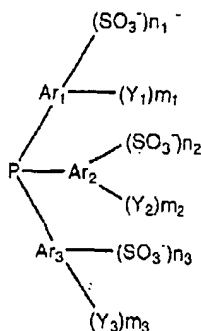
VIII B of the periodic system of elements.

[0027] Preferably the above substituted imidazolium salts are used as a solvent in organic reactions selected from the group consisting of the catalytic conversion of olefins selected from the telomerisation of conjugated dienes, the dimerisation of olefins, the oligomerisation of olefins, the polymerisation of olefins, the alkylation of olefins, the hydrogenation of olefins, the olefin metathesis, the hydroformylation of olefins, the ring-closing metathesis of olefins, the ring-opening metathesis polymerisation of olefins, the symmetric or asymmetric epoxidation of olefins (including heteroatom substituted olefins) and the cyclopropanation of olefins, the condensation reaction, the hydrogenation of, in particular, aldehydes, the isomerization reaction, the Suzuki cross-coupling reactions, the amination reaction, the partial oxidation of alkanes, the kinetic resolution of racemic mixtures, the hydrogenation of imines, the hydrogenation of ketones, the transfer hydrogenation, and the hydroxylation of aromatic organic compounds.

[0028] A particular preferred process is the telomerization of conjugated dienes.

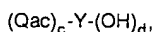
[0029] In some cases the 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, or mixtures thereof, with the exception of 1,2,3,4,5-pentamethyl imidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium-, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with sulfonated or carboxylated triesters of phosphorous acid as anion, act also as a catalyst, and accordingly the present invention is also related to the use of the above imidazolium salts as a catalyst or catalyst component, in particular in transition metal catalyst systems. This is particularly true in those cases where the anion of the imidazolium salt is a phosphorous containing anion like anions of the aforementioned sulfonated or carboxylated (alkyl and/or aryl) phosphines or phosphites.

[0030] Such anions are disclosed for example in EP-A-0 924 218 (US 6,103,908) and shall be included within the scope of the present invention. EP-A-0 924 218 discloses nonaqueous ionic liquid of the formula $(Q^+)_a A^{a-}$, wherein Q^+ is a singly charged quaternary ammonium and/or phosphonium cation or the equivalent of a multiply charged ammonium and/or phosphonium cation and A^{a-} is a triarylphosphine anion of the formula:



where Ar_1 , Ar_2 and Ar_3 are individually aryl of 6 to 14 carbon atoms, the substituents Y_1 , Y_2 and Y_3 are individually selected from the group consisting of alkyl and alkoxy of 1 to 4 carbon atoms, chlorine, bromine, hydroxyl, cyano, nitro and amino groups of the formula NR^6R^7 , where R^6 and R^7 are individually hydrogen or alkyl of 1 to 4 carbon atoms, m_1 , m_2 and m_3 are individually integers from 0 to 5, n_1 , n_2 and n_3 are individually integers from 0 to 3, where at least one of n_1 , n_2 and n_3 is equal to or greater than 1, and a is $n_1+n_2+n_3$, and amines and/or phosphines derived from Q^+ are present in an excess of up to 5 equivalents over the stoichiometrically required amount for the formation of $(Q^+)_{a-} A^{a-}$ or alkali metal or alkaline earth metal salts of the triarylphosphines A^{a-} are present in an excess of up to 5 equivalents over the stoichiometrically required amount for the formation of $(Q^+)_{a-} A^{a-}$.

[0031] Similarly the above mentioned not prior published German patent application n° 19919494.7 (corresponding to international patent application n° PCT/EP00/03499) discloses suitable nonaqueous ionic liquid of the formula $(Q_1^+)_{a-} A^{a-}$, wherein Q_1^+ is a singly charged ammonium cation, optionally substituted with organic group(s), or the equivalent of a multiply charged ammonium cation and A^{a-} is an anion of a sulfonated or carboxylated triester of phosphorous acid and b is an integer of at least one. These ammonium salts of sulfonated or carboxylated phosphorous acids may be formally derived from phosphorous acid by esterification with the ammonium salts of hydroxysulfonic acids or hydroxycarboxylic acids of the following general formula



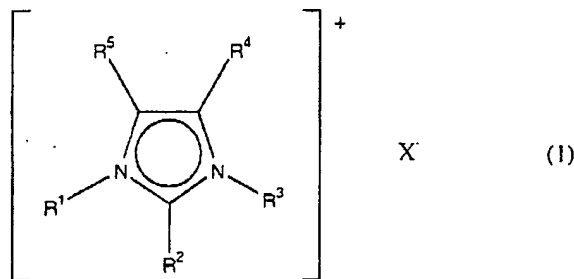
wherein ac is the acid residue, namely the sulfonic acid residue $-\text{SO}_3^-$, and the carboxylic acid residue, respectively and Q is as already mentioned a singly charged ammonium cation, optionally substituted with organic group(s), or the equivalent of a multiply charged ammonium cation, Y represents an organic residue and is preferably a branched or non-branched saturated aliphatic hydrocarbon group having a total of up to 20 carbon atoms, optionally substituted by hydroxy or C1-C10 alkoxy, c and d are integers of at least 1, d is preferably 1 or 2. Also these anions of sulfonated or carboxylated phosphorous acids, in particular, sulfonated aryl or carboxylated aryl phosphorous acids may be used as anions of the imidazolium cations in accordance with the present invention.

[0032] Further the present invention is related to the use of the above mentioned 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, or mixtures thereof, with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium-, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with a sulfonated or carboxylated triester of phosphorous acid as anion, in a two-phase catalytic reaction, preferably as solvent and/or catalyst component.

[0033] The present invention is also related to the use of 1,2,3- and/or 1,2,3,4- and/or 1,2,3,4,5-substituted imidazolium salts, in particular those defined above, with a metal compound catalyst or catalyst component, in particular in organic reactions as defined above. The salts can have a role of solvent and possibly of catalyst or catalyst component, preferably solvent.

[0034] The use of salts containing chiral group(s) leading to a chiral solvent may advantageously confer enantioselectivity to the reaction wherein they are used.

[0035] Still further the present invention is related to new imidazolium salts of the following formula (I):



wherein R^1 and R^3 are the same or different and are each selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms, and a tri(C1-C6) alkylsilyl group,

R^2 is selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms and a halogen atom; more preferably, R^2 is an alkyl or an aryl group.

R^4 and R^5 are the same or different and are each selected from the group consisting of hydrogen, a chiral or achiral alkyl group having up to 10, preferably up to 6 carbon atoms, a chiral or achiral aryl group of 6 to 10 carbon atoms, a chiral or achiral tri(C1-C6)alkylsilyl group, and a halogen atom; more preferably, R^4 and R^5 are chosen among hydrogen, or an alkyl, aryl or tri(C1-C10)alkylsilyl group, still more preferably hydrogen, and X^- represents an anion,

with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts of sulfonated or carboxylated triesters of phosphorous acid, 1,2,3,4,5-pentamethylimidazolium iodide, 1,2,3-trimethylimidazolium bromide, 1,2,3-trimethylimidazolium iodide, 1,2-dimethyl-3-ethylimidazolium bromide, 1,2-dimethyl-3-ethylimidazolium chloride, 1,2-dimethyl-3-butylimidazolium fluoride, 1-butyl-2,3-dimethylimidazolium salt of 2,2'-(2,5-cyclohexadiene-1,4-ylidene)bis[propanedinitril], 1,3-dimethyl-2,4,5-trichloroimidazolium tetrafluoroborate, 1,3-dimethyl-2,4,5-tribromoimidazolium tetrafluoroborate, 1,3-dimethyl-2,4,5-tribromoimidazolium bromide.

[0036] With respect to the explanation of the substituents it is referred to the definitions and preferred definitions given above.

[0037] Particular preferred imidazolium salts of the invention are 1-n-butyl-2,3-dimethylimidazolium bistrifluoro (C1-C10, preferably Cl (methyl))alkylsulfonylamide, 1-n-butyl-2,3-dimethylimidazolium tetrafluoroborate and 1-n-butyl-2,3-dimethylimidazolium hexafluorophosphate.

[0038] The present invention also concerns compositions or mixtures comprising at least one 1,2,3- or 1,2,3,4- or

1,2,3,4,5-substituted imidazolium salt, in particular as defined above, as a solvent; and at least one transition metal or at least one catalyst, in particular a catalyst comprising a transition metal compound; transition metal may be in particular from group VIII B, e.g. as further defined herein. The catalyst can be any catalyst usually used in the catalytic reactions defined above. The composition may also comprise the reactant(s).

[0039] These compositions or mixtures may comprise salts as defined above with the specified both kind of exceptions.

[0040] Such compositions or mixtures may also comprise a phosphorus-containing compound as defined herein-after.

[0041] The amount of these phosphorus-containing compounds is in general from 0.01 to 100, preferably from 1 to 20, in particular from 1 to 5, mol per mole of the transition metal.

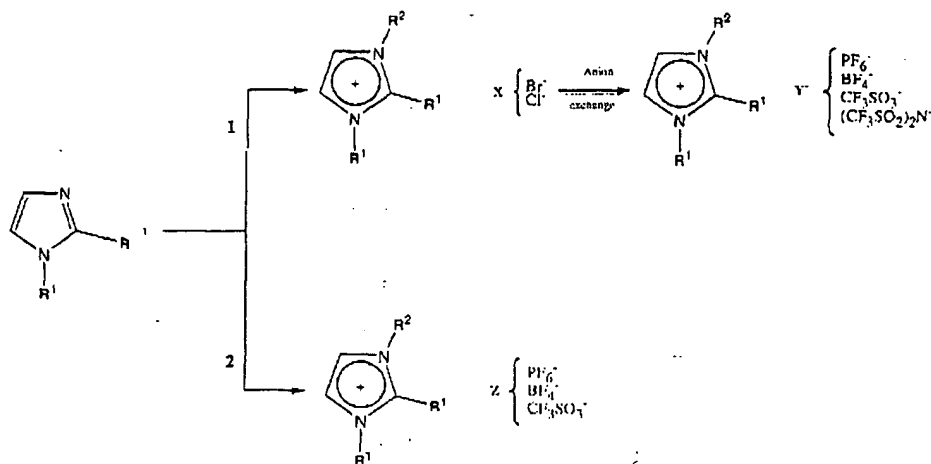
[0042] The concentration of the transition metal is usually in the range of 1 to 200 mM per liter of ionic liquid and more preferably 10 to 50.

[0043] The amount of the salt in the reaction system is usually 5 to 100 parts per 100 parts of the reactant(s), e.g. diolefin, preferably 10 to 50.

[0044] Usually the imidazolium salts have a melting point of below 200 °C, preferably below 160 °C, more preferably below 140 °C, still more preferably below 120 °C, and most preferably below 100 °C, in particular, below 90 °C (the melting points are measured at normal pressure with a digital apparatus such as of Electrothermal).

[0045] 1-n-Butyl-2,3-dimethylimidazolium chloride (BMMI⁺Cl⁻) has a melting point of 104-105 °C, 1-n-butyl-2,3-dimethylimidazolium bistrifluoromethylsulfonamide (BMMI⁺TF₂N⁻), and 1-n-butyl-2,3-dimethylimidazolium tetrafluoroborate (BMMI⁺BF₄⁻) are liquids at room temperature.

[0046] Synthesis of non aqueous ionic liquids based on unsymmetrically substituted 1,2,3-trialkylimidazolium can be performed following two main schemes. In the first, the N-alkylimidazole or 1,2-dialkylimidazole (generally commercial products) are alkylated with an organic halide and the desired salt is then obtained by an anion exchange reactions (metathesis). In the second, the liquid is obtained directly by the quaternization of an N-alkylimidazole, with the alkylating agent itself providing a suitable anion



[0047] For the indirect route (1) one can refer to P. Bonhote, A.-P. Dias, N. Papageorgiou, K. Kalyanasundaram, Gratzel, M. Inorg. Chem. **1996**, 35, 1168-1178; J. S. Wilkes, M. J. Zaworotko, J. Chem. Soc., Chem. Commun. **1992**, 965-967; J. Fuller, R. T. Carlin, R. A. Osteryoung, J. Electrochem. Soc. **1997**, 144, 3881-3886. Generally, bromide or chloride imidazolium can be used as intermediate in the synthesis of the final ionic liquid. The anion exchange involved in the second step can be performed in different solvents: water (see J. D. Holbrey, K. R. Seddon, J. Chem. Soc., Dalton Trans. **1999**, 2133-2139) or acetone (see P. A. Suarez, J. E. L. Dullius, S. Einloft, R. F. de Souza, J. Dupont, Polyhedron, **1996**, 15, 1217-1219 and P. A. Suarez, S. Einloft, J. E. L. Dullius, R. F. de Souza, J. Dupont, J. Chim. Phys., **1998**, 95, 1626-1639).

[0048] The direct synthesis route (2) allows one to obtain an ionic liquid without any addition of halide by the reaction of an N-alkylimidazole with an appropriate alkylating agent. The alkylating agent must be able to realize both the quaternization of the imidazole ring and the introduction of a non-coordinating anion. Can be used, alkylating agents derived from alkyltriflates (methyl and ethyltriflate) (see P. Bonhote, A.-P. Dias, N. Papageorgiou, K. Kalyanasundaram,

Gratzel, M. Inorg. Chem. **1996**, 35, 1168-1178). Reaction is carried out in refluxing of 1,1,1-trichloroethane, a solvent chosen for its stability toward strongly alkylating agents and the insolubility of the imidazolium salts in this milieu. To prevent alkyltriflate hydrolysis the reaction must be conducted under dry argon. Nearly quantitative yields were obtained.

[0049] The syntheses of $[R^1R^2][BF_4]$ and $[R^1R^2][PF_6]$ salts can be prepared using the first route which involves metathesis reaction from the corresponding chloride or bromide salts with $NaBF_4$ and $NaPF_6$ in water (see J. D. Holbrey, K. R. Seddon, J. Chem. Soc., Dalton Trans, **1999**, 2133-2139), methanol (see J. S. Wilkes, M. J. Zaworotko, J. Chem. Soc., Chem. Commun. **1992**, 965-967), or acetone (see P. A. Suarez, J. E. L. Dullius, S. Einloft, R. F. de Souza, J. Dupont, Polyhedron, **1996**, 15, 1217-1219). They can also be obtained by using other alkylating agents. Those are triethyloxonium tetrafluoroborate and triethyloxonium hexafluorophosphate. As with ethyltriflate, the oxonium salt $[Et_3O][BF_4]$ reacts with one equivalent of 1-alkylimidazole (or 1,2-dialkylimidazole) in refluxing of methylene dichloride with very high yields (see H. Olivier, F. Favre, IFP, FR 2.779.143, **1998**) All the imidazolium ionic liquids prepared were air stable under ambient conditions and may be handled under normal laboratory conditions.

[0050] The use of the present invention is now exemplified further in a process for telomerizing conjugated dienes.

[0051] The catalytic dimerization of dienes under the concomitant addition of a nucleophilic reagent was reported simultaneously in 1967 by Smutny at Shell and Takahashi at Osaka University. The reaction is defined under the general term of telomerization as the dimerisation of two conjugate diolefins (telomers) together with the addition of a third molecule (telogen) over one double bond equivalent.

[0052] Usually the process for telomerizing a conjugated diene is carried out in the presence of a transition metal compound and a phosphorus-containing compound.

[0053] The conjugated diene preferably has 4 to 6 carbon atoms. Particularly preferred the conjugated diene is selected from butadiene, isopropene or 1,3-pentadiene. The most preferred conjugated diene is butadiene.

[0054] Telogens can be for example a compound containing active hydrogen, preferably a compound of the general formula

H-A

wherein A is selected from the group consisting of hydroxy, alkoxy, cycloalkoxy, hydroalkoxy, alkenyloxy, aryloxy, alkanoloxo, mono- or dialkylamino, tri(alkyl- and/or aryl)silyl, and an alkyl group substituted in the α -position with at least one electron attracting group, preferably selected from alkoxycarbonyl, alkanoyl and/or cyano, wherein the above mentioned alkyl moieties independently from each other are branched or linear and each may have up to 8 carbon atoms, and wherein the above mentioned aryl moieties independently from each other may have up to 10 carbon atoms.

[0055] Thus the compound containing active hydrogen includes for example water, alkanols like methanol, ethanol, n-propanol, isopropanol, n-butanol, iso-butanol, sec. butanol etc., cycloalkanols like cyclohexanol etc., alkandols like glycol, triethyleneglycol, polyethylene glycol, 1,2- or 1,3-propandiol etc., alkenols like allyl alcohol etc., aromatic alcohols like phenols, naphthols etc., carboxylic acids like acetic acid etc., amines like primary or secondary amines like methyl amine, ethyl amine, dimethyl amine, diethyl amine etc., tri(alkyl- and/or aryl) silanes, like trimethyl silane, triethyl silane, triphenyl silane, phenyldimethyl silane etc., and CH-acidic compounds with activated methylene groups (so-called "Michael-Donors" like malonic acid dialkyl esters, acetic acid alkyl esters etc.

[0056] Particularly preferred telogens are water, methanol and glycol, and the most preferred is methanol.

[0057] The transition metal compound can be any transition metal compound suitable for catalysis of the telomerization reaction in the presence of the phosphorous compound and the salt. Preferably it is a compound of an element of the group VIII B (or 8, 9 and 10) of the periodic system of elements, that is a compound of iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium or platinum. More preferred compounds are selected from compounds of cobalt, rhodium, nickel, platinum and platinum. Concerning possible transition metal compounds for carrying out the telomerization process it is referred to A. Behr in "Aspect of Homogeneous Catalysis, A series of Advances; Edited by R. Ugo; D. Reidel Publishing Company; Vol. 5; pp. 3-73; 1984" - Tsuji, J. *Adv. Organomet. Chem.* **1979**, 17, 141 - W. Keim : in « *Transition Metals in Homogeneous Catalysis* », Ed. G. N. Schrauzer, p 59, Marcel Dekker, New York, **1971**. - R. Baker, *Chem. Rev.*, 73, 487, **1973** - P. N. Rylander in « *Organic Chemistry* », vol 28, p 175, Academic Press, New York, **1973**.

[0058] Most preferred are palladium compounds, for example, known palladium compounds used in telomerization processes for example those described in US 5,043,487, US 4,356,333, US 4,142,060, EP-A-0,436,226, WO 98/08794, WO 96/30636 and US 4,417,079 the relevant content of which is herein incorporated by reference.

[0059] Examples of these palladium compounds include soluble palladium(0) and palladium(II) compounds, for example, palladium acetylacetonate, π -allylpalladium acetate, π -allylpalladium chloride, palladium acetate, palladium carbonate, palladium nitrate, palladium chloride, sodium chloropalladate, bis(benzonitrile)palladium chloride, bis(triphenylphosphine)palladium chloride, bis(triphenylphosphine)palladium acetate, bis(1,5-cyclooctadiene)palladium

and bis(π -allyl)palladium.

[0060] A particular preferred palladium compound is palladium acetate ($\text{Pd}(\text{OAc})_2$).

[0061] The active species of the transition metal compound is a low-valence transition metal complex which may be formed by reduction in the presence of butadiene or by suitable reducing agents added.

[0062] The transition metal compound can be present in the reaction system in any optional amount but, from the standpoint of commercial production, the transition metal compound is preferably present in such an amount as to assure the concentration of transition metal atom of 0.1 to 50 mg atoms, more preferably 0.5 to 5 mg atoms per liter of the reaction mixture.

[0063] The ratio of the transition metal compound to the conjugated diene is not critical, but is preferably from 10^{-5} to 10^{-1} , in particular from 10^{-4} to 10^{-2} , mol of the transition metal per mole of the conjugated diene.

[0064] The phosphorus-containing compound which forms part of the catalyst system is not particularly restricted but can be any phosphorus-containing compound, capable of coordinating to the transition metal compound, for example hydrophobic or hydrophilic, water-soluble, mono- or bidentate phosphorus-containing compounds known for telomerization processes (e.g. those known from US5043487, US5345007, US4356333, EP-A-0436226, WO98/08794, WO95/30636, US4417079 and US4142060 the relevant content of which is herein incorporated by reference).

[0065] Suitable examples include phosphines or phosphites, preferably mono- or bidentate alkylphosphines, arylphosphines, arylalkylphosphines, alkylphosphites, arylphosphites, and arylalkylphosphites, wherein the hydrocarbon moieties independently each may have up to 36 carbon atoms, preferably 24 carbon atoms, more preferably 10 carbon atoms and may be substituted by one of three suitable substituents preferably selected from a sulfonic acid group or a salt thereof, a carboxylic acid group or a salt thereof and an alkyl group. Salts of the sulfonic acid or carboxylic acid group include for example alkali metal salts like sodium or potassium salts and ammonium salts.

[0066] Examples of these phosphines or phosphites include tributylphosphine, dimethyl-n-octylphosphine, tricyclohexylphosphine, triphenylphosphine (TPP), tritolyphosphine, tris(p-methoxyphenyl)phosphine, diphenylethylphosphine, dimethylphenylphosphine, 1,2-bisdiphenylphosphinoethane, triethyl phosphite, tricyclohexyl phosphite and triphenylphosphite, hydrophilic arylphosphines, like sulfonated or carboxylated arylphosphines, preferably watersoluble salts of mono-, di- or trisulfonated triphenylphosphine compounds like trisodium tris(m-sulfonatophenyl)phosphine (TPPTS), bis(p-sulfonatophenyl)phenylphosphine dihydrate dipotassium salt (TPPDS) and diphenylphosphinobenzene-3-sulfonic acid sodium salt (TPPMS).

[0067] In general, the phosphines are preferred to the phosphites since the latter depending on the telogen used may undergo hydrolysis and rearrangement reactions. Particularly preferred are aryl phosphine compounds, sulfonated or not, like the above mentioned TPP, TPPTS, TPPDS and TPPMS.

[0068] Such phosphorus-containing compounds can be present in the compositions or mixtures defined above without being limited to a telomerization process.

[0069] The amount of these phosphorus-containing compounds is in general from 1 to 100, preferably from 1 to 20, in particular from 1 to 5, mol per mole of the transition metal,

[0070] Depending on the telogen, to be telomerized, the phosphorus-containing compound used as the catalyst component and the relative amounts of the reactants in some instances monophasic reaction systems may be formed. These monophasic reaction systems can be usually transferred into biphasic systems by addition of at least one non-polar solvent (usually a solvent which is immiscible with water). Thereby a phase consisting of the solvent and the product (usually the upper phase) and a phase consisting of the salt (or ionic liquid) and the major part of catalyst (usually the lower phase) are formed. In some cases, depending on the telogen used and the catalyst system part of the catalyst may be contained also in the product phase. The non-polar solvent may include for example aliphatic hydrocarbons, for example alkanes like pentane, hexane, heptane, and octane etc., cycloalkanes like cyclopentane, cyclohexane etc., aromatic hydrocarbons like benzene, toluene, xylene etc. and aliphatic or aromatic ethers, like diethyl ether, tetrahydrofuran, anisol, methyl-*tert*-butyl ether (MTBE), diethylene glycol, dimethoxyethane, etc. The present invention includes also the case where the imidazolium salts are used together with such conventional non-polar solvent solvents and/or polar solvents, like water. A particular preferred non-polar solvent is n-heptane.

[0071] Depending on the telogen the desired products are for example trans- and cis-1-methoxy-2,7-octadiene and 3-methoxy-1,7-octadiene for methanol, cis- and trans- 2,7-octadiene-1-ol and 1,7-octadiene-3-ol for water, and cis- and trans- 1-hydroxy-2-(2,7-octadienyl-1-oxy) ethane and 1-hydroxy-2-(1,7-octadienyl-3-oxy) ethane for glycol.

[0072] The obtained unsaturated products can be hydrogenated catalytically into the corresponding saturated compounds in a known manner.

[0073] The telomerization reaction is usually performed under a pressure of from normal pressure to 200 bar, preferably from normal pressure to 30 bar.

[0074] The temperature of the telomerization reaction is usually in the range of 20 to 200 °C preferably of 30 to 180 °C, more preferably of 40 to 140 °C and still more preferably of 40 to 120 °C.

[0075] The concentration of the transition metal is usually in the range of 1 to 200 mM per liter of ionic liquid and

more preferably 10 to 50.

[0076] The amount of the salt in the reaction system is usually 5 to 100 parts per 100 parts of the diolefin, preferably 10 to 50.

[0077] The molar ratio of telogen/conjugated diolefin is usually in the range 0.5 to 10, preferably 0.5 to 5.

[0078] As generally known, the telomerisation of butadiene with water as the telogen is preferably carried out in the presence of a base and under CO₂-pressure. Suitable bases include for example the hydroxides of alkali metals and alkaline earth metals and amines. Suitable amines include for example tertiary amines having a basicity constant (pK_a) of at least 7, for example tri(C1-C6)alkylamines such as trimethylamine, triethylamine, tri-n-propylamine, tri-n-butylamine, etc.; aminoalcohols such as 1-N,N-dimethylamino-2-propanol, 1-N,N-dimethylamino-3-butanol, etc.; and N,N-dimethyl-2-methoxyethylamine, N,N-dimethyl-3-ethoxypropylamine, N-methylpyrrolidine, N-methylpiperidine, N-methylmorpholine, N,N'-dimethylpiperazine, N,N,N',N'-tetramethyl-1,3-butanediamine and the like. Among these, triethylamine is most preferred.

[0079] Further carbonate and/or bicarbonate ions may be present along with the tertiary amine to accelerate the rate of n-octadienol formation. Carbonate and bicarbonate ions are conveniently derived from carbon dioxide, sodium bicarbonate or formic acid which releases these ions in the reaction system. Among these, carbon dioxide is most preferred.

[0080] The amount of carbon dioxide which promotes the butadiene telomerization is not critical and may range from about 10⁻³ to 1, preferably from 10⁻² to 0.5, mol per mole of the conjugated diene.

[0081] The substituted 1,2,3-, 1,2,3,4- and 1,2,3,4,5- substituted imidazolium salts of the present invention can be used as a solvent for the hydrodimerization with rates under the conditions already known.

[0082] In the following examples the use according to the present invention is exemplified in the catalytic conversion of conjugated dienes (telomerization) and oligomerization of dienes. It is however to be understood that the present invention is not limited to such uses.

[0083] Fig. 1 shows the apparatus for telomerizing butadiene which has been used in the examples.

[0084] Fig. 2 shows an embodiment of a two-phase process of telomerization of butadiene (C₄H₆) with MeOH or ethylene glycol in the ionic liquids in accordance with the present invention.

Examples

A. Preparation of non-aqueous ionic liquids

a- Materials

[0085] All the syntheses were carried out under dry argon using standard Schlenk techniques. Methylene dichloride was distilled over P₂O₅ and stored over 0.3 nm molecular sieves. All other reagents (1,2-dimethylimidazole, pyridine, HPF₆, 1-chlorobutane) were purchased from Aldrich and used as is, unless otherwise indicated.

h- Physicochemical measurements

[0086] Proton and carbon NMR were recorded on a Bruker AC 300 MHz using CD₂Cl₂ (from SDS) as solvent and SiMc₄ (from Aldrich) as internal standard. Melting point of solid salts was measured on a digital apparatus from Electrothermal.

c- Syntheses

[0087] The following salts were prepared according to known procedures (see e.g. for [EMI][Br], [EMI][TF₂N], [EMI][CF₃SO₃], [BMI][TF₂N] «Bonhôte, P.; Dias, A.-P.; Papageorgiou, N.; Kalyanasundaram, K.; Gratzel, M. *Inorg. Chem.* **1996**, *35*, 1168-1178 »; for [BMI][BF₄] « Holbrey, J. D.; Seddon, K. R. *J. Chem. Soc., Dalton Trans.* **1999**, 2133-2139 »; for

[BMI][PF₆] «Suarez, P. A. Z.; Dullius, J. E.L.; Einloft, S.; de Souza, R. F.; Dupont, J. *Polyhedron* **1996**, *15*, 1217-1219 »

EMI⁺Br⁻ (1-ethyl-3-methylimidazolium bromide),

EMI⁺TF₂N⁻ (1-ethyl-3-methylimidazolium bistrifluoromethylsulfonamide),

EMI⁺CF₃SO₃⁻ (1-ethyl-3-methylimidazolium trifluoromethylsulfonate),

BMI⁺Cl⁻ (1-n-butyl-3- methylimidazolium chloride),

BMI⁺PF₆⁻ (1-n-butyl-3- methylimidazolium hexafluorophosphate),

BMI⁺TF₂N⁻ (1-n-butyl-3- methylimidazolium bistrifluoromethylsulfonamide), and

BMI⁺BF₄⁻ (1-n-butyl-3- methylimidazolium tetrafluoroborate).

Preparation example 1

1-butyl-2,3-dimethylimidazolium chloride [BMMI][Cl]:

[0088] Freshly distilled 1-chlorobutane (88 g, 0.96 mol) was added in one portion to a 500 ml thick walled glass reactor equipped with a magnetic stirrer containing 1,2-dimethylimidazole (65 g, 0.68 mol). The reactor was scaled and the solution was stirred for 16 h at 100 °C (note: the reaction pressure was in excess of 2 atm). Reactor was degassed and the hot solution was transferred (under argon) in a round bottom flask containing acetonitrile (95 ml). The solution was added dropwise under vigorous stirring to toluene (500 ml). A precipitate formed and was filtered, washed with toluene (3 X 100 ml) and dried overnight under vacuum. [BMMI][Cl] was obtained (89.73 g, 70% yield) as a white hygroscopic solid. ¹H NMR (CD₂Cl₂): δ 0.97 [t, ³J=7.15 Hz, NCH₂CH₂CH₂CH₃]; 1.39 [sext, ³J=7.5 Hz, NCH₂CH₂CH₂CH₃]; 1.80 [quint, ³J=7.4 Hz, NCH₂CH₂CH₂CH₃]; 2.75 [s, CCH₃]; 4.00 [s, NCH₃]; 4.19 [t, ³J=7.1 Hz, NCH₂CH₂CH₂CH₃]; 7.52 [s, CH]; 7.84 [s, CH]; ¹³C NMR (CD₂Cl₂): δ 10.70 [NCH₂CH₂CH₂CH₃]; 13.74 [NCH₂CH₂CH₂CH₃]; 19.96 [NCH₂CH₂CH₂CH₃]; 32.26 [CCH₃]; 36.09 [NCH₃]; 48.94 [NCH₂CH₂CH₂CH₃]; 121.72 [CH]; 123.64 [CH]; 144.03 [CCH₃]; Elemental analysis (calculated): %C=57.14 (57.29), %H=9.08 (9.08), %N=14.85 (14.85). Mp = 104-105 °C.

Preparation example 2

1-butyl-2,3-dimethylimidazolium bistrifluoromethylsulfonamide [BMMI][TF₂N]:

[0089] A solution of lithium bis((trifluoromethyl)sulfonyl)amide (41.9 g, 0.149 mol) in 100 ml of H₂O was added dropwise to a solution of [BMMI][Cl] (24.32 g, 0.129 mol) in 150 ml of H₂O. The solution was stirred at 70°C for 2 h and then cooled to room temperature. Methylene dichloride (50 ml) was added, and all was transferred to a separatory funnel. The lower phase (ionic liquid + CH₂Cl₂) was collected. Tonic liquid was purified through a short alumina column, and the CH₂Cl₂ removed on a Rotavapor. The resultant hydrophobic liquid was washed 3 times with 150 ml of H₂O and dried for 3 h at 50 °C under vacuum to afford [BMMI][TF₂N] (44.1 g, 78.9 % yield) as a colorless liquid. ¹H NMR (CD₂Cl₂): δ 0.97 [t, ³J=7.15 Hz, NCH₂CH₂CH₂CH₃]; 1.37 [sext, ³J=7.5 Hz, NCH₂CH₂CH₂CH₃]; 1.78 [quint, ³J=7.4 Hz, NCH₂CH₂CH₂CH₃]; 2.59 [s, CCH₃]; 3.79 [s, NCH₃]; 4.04 [t, ³J=7.1 Hz, NCH₂CH₂CH₂CH₃]; 7.19 [s, CH]; 7.21 [s, CH]; ¹³C NMR (CD₂Cl₂): δ 9.78 [NCH₂CH₂CH₂CH₃]; 13.53 [NCH₂CH₂CH₂CH₃]; 19.86 [NCH₂CH₂CH₂CH₃]; 31.90 [CCH₃]; 35.60 [NCH₃]; 49.00 [NCH₂CH₂CH₂CH₃]; 121.37 [CH]; 122.91 [CH]; 144.21 [CCH₃]; 120.50 [q, J_{CF}= 321.4 Hz, (CF₃SO₂)₂N]; Elemental analysis (calculated): %C=30.68 (30.49), %H=3.96 (3.95), %N=9.66 (9.70), %Cl < 250 ppm (0)

Preparation example 3

1-butyl-2,3-dimethylimidazolium tetrafluoroborate [BMMI][BF₄]:

[0090] Procedure previously described for the synthesis of [BMMI][TF₂N] was used (except the washes with water). From 22.23 g (0.118 mol) of [BMMI][Cl] and 15.52 g (0.141 mol) of sodium tetrafluoroborate, there were obtained 25.33 g (90 % yield) of [BMMI][BF₄] as a colorless, very viscous and hydrophilic liquid. ¹H NMR (CD₂Cl₂): δ 0.96 [t, ³J=7.15 Hz, NCH₂CH₂CH₂CH₃]; 1.38 [sext, ³J=7.5 Hz, NCH₂CH₂CH₂CH₃]; 1.78 [quintet, ³J=7.4 Hz, NCH₂CH₂CH₂CH₃]; 2.60 [s, CCH₃]; 3.80 [s, NCH₃]; 4.06 [t, ³J=7.1 Hz, NCH₂CH₂CH₂CH₃]; 7.25 [dd, CH]; 7.30 [dd, CH]; ¹³C NMR (CD₂Cl₂): δ 9.58 [NCH₂CH₂CH₂CH₃]; 13.61 [NCH₂CH₂CH₂CH₃]; 19.79 [NCH₂CH₂CH₂CH₃]; 31.94 [CCH₃]; 35.36 [NCH₃]; 48.70 [NCH₂CH₂CH₂CH₃]; 121.30 [CH]; 122.88 [CH]; 144.31 [CCH₃]; Elemental analysis (calculated): %C=45.09 (45.03), %H=7.25 (7.14), %N=11.52 (11.67), %Cl=0.11 (0)

B- Catalysis**a- Materials**

[0091] $\text{Pd}(\text{OAc})_2$ (98 %) was purchased from Strem Chemicals, stored under argon and used without further purification. Triphenylphosphine (PPh_3) was obtained from Aldrich, trisodium tris((*m*-sulfonatophenyl)phosphine) (TPPTS) from the lab reserves, bis(*p*-sulfonatophenyl)phenylphosphine dihydrate dipotassium salt (TPPDS) from Strem Chemical and diphenylphosphinobenzene-3-sulfonic acid sodium salt (TPPMS) from TCI. Those phosphines were stored under argon and used as is. Triethylamine (Fluka >98%) and dimethyldodecylamine (Aldrich 97%) were distilled under argon, freeze-pumped and degassed with argon just before use. Water used in all experiments was deionized and degassed by freeze-pumping and bubbling of argon. Methanol was obtained by refluxing over Mg/I_2 and stored over 3 Å molecular sieves. Anhydrous ethylene glycol was obtained from Aldrich. Heptane was distilled over Na/K and stored over 3 Å molecular sieves under argon. Carbon dioxide (N45) and butadiene (N25) were obtained from « Air-Liquide » and used directly from cylinders.

b. Catalytic experiments and analyses**Catalytic runs:**

[0092] All catalytic reactions were performed in a 100 ml magnetically stirred stainless steel autoclave equipped with an inner glass sleeve and an internal thermocouple under argon atmosphere as shown in Figure 1. In a typical reaction, $\text{Pd}(\text{OAc})_2$, phosphine, ionic liquid, telogen (methanol, ethylene glycol or water) and eventually heptane and/or amine are introduced in a schlenk and then transferred into the purged autoclave via a ball valve. The autoclave was cooled to $T < -10^\circ\text{C}$ and the desired mass of butadiene was transferred from a lecture bottle resting on a scale (for telomerization of butadiene with water reactions, this step is followed by the warming to room temperature of the autoclave in order to introduce 5 bar of carbon dioxide). The reactor was then heated to the desired reaction temperature. After the selected reaction time, the autoclave was cooled to 40°C and butadiene was condensed in a volumetric glass cylinder cooled to -78°C . The volume of the liquid condensed in the cylinder (determined to be almost pure butadiene) was noted. The autoclave was then warmed to room temperature. The remaining liquid phases in the autoclave were recovered, weighed and further analyzed (GC, GC-MS and NMR).

[0093] Thus are obtained two measures of butadiene conversion, from the volume of unreacted butadiene condensed in the graduated cylinder (Conv. A) and the mass increase of the liquid solution in the autoclave (Conv. B). Conversion A is very often higher than conversion B due to possible loss of butadiene during trapping. Exact conversion will be considered as the average between conversion A and conversion B.

Work-up:

[0094] When at the end of the run only a single liquid phase was present, a sample was analyzed without further treatment. When multiple phases were present, only the upper phase was analyzed for product.

Analyses:

[0095] The identification of the telomerization products was carried out both by Hewlett-Packard GC/MS and NMR analyses. Finally they were quantitatively analyzed by gas chromatography on a HP6890 chromatograph equipped with FID detector and a HP1 column ($L = 30\text{ m}$, $\phi_{\text{int}} = 0.32\text{ mm}$, film thickness = $0.25\text{ }\mu\text{m}$). Injector temperature was 170°C and detector temperature was 180°C . The temperature program was from 60°C (3 mn) to 100°C (0 mn) at a heating rate of $10^\circ\text{C} / \text{mn}$ to 220°C (30 mn) at a heating rate of $5^\circ\text{C} / \text{mn}$.

c- Data presentation**Abbreviations :**

[0096]

- OT: 1,3,7-octatriene and 1,3,6-octatriene
- VCH: 4-vinyl-cyclohexene
- Oligo.: products containing three and more units of butadiene
- 1-OMe: (*cis* + *trans*)-1-methoxy-2,7-octadiene

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- 3-OMe : 3-methoxy-1,7-octadiene
- 1-OI : 1-hydroxy-2,7-octadiene
- 3-OI : 3-hydroxy-1,7-octadiene
- 1-OGly : (*cis* + *trans*) 1-hydroxy-2-(2,7-octadienyl-1-oxy) ethane
- 3-OGly : 1-hydroxy-2-(1,7-octadienyl-3-oxy) ethane
- (1+3)-Gly : bis(octadienyl-1-oxy)-1,2-ethane + bis(octadienyl-3-oxy)-1,2-ethane

Conversions and selectivities are defined by the following equations:

[0097]

- Conv. A % was calculated from unreacted butadiene remaining after reaction

$$\text{Conv. A} = \frac{\text{mass of butadiene introduced} - \text{mass of butadiene recovered}}{\text{mass of butadiene introduced}}$$

- Conv. B % was calculated from the increase in the mass of the reactor

$$\text{Conv. B} = \frac{\text{increase of the mass of reactor contents}}{\text{mass of butadiene introduced}}$$

- GC selectivities toward products X were evaluated as :

$$\text{GC. Sel. (X)} = \frac{\text{moles of product X}}{\sum (\text{moles of products})}$$

- Selectivities to linear telomers (in the tables comprehensively reported as Ratio 1 / 3) were evaluated as :

$$\text{Ratio 1 / 3} = \frac{\text{moles of linear telomer}}{\text{moles of branched telomer}}$$

Turn over number in mol C₄H₆ / mol Pd was evaluated as :

[0098]

$$\text{TON} = \frac{\text{mole of butadiene converted (average of Conv. A and Conv. B)}}{\text{moles of palladium}}$$

Determination of the palladium leaching in the organic phase :

[0099]

$$\% \text{ Pd leaching} = \frac{\text{mass of Pd in the organic phase}}{\text{mass of initial Pd}}$$

[0100] The analytical procedure consists in evaporating the organic products and solubilizing the residue in a mixture of HNO₃ / HCl. Palladium contained in this mixture was then quantified by ICP/SM.

d- Catalysis examples (Cat. Ex.) and Comparative catalysis examples (Comp. Cat. Ex.)

[0101] Using the telomerization apparatus described above catalysis examples and comparative catalysis were carried out under the conditions indicated in the following.

Catalysis examples 1 to 3

[0102] Catalysis examples 1 to 3 for telomerizing 1,3-butadiene with methanol were run using Pd(OAc)₂ / PPh₃ as the catalyst system. Table 1 shows the results.

Table 1:

Telomerization of 1,3-butadiene with methanol in the presence of Pd(OAc) ₂ /PPh ₃ (a)										
Cat. Ex.	Ionic Liquid	Conv A	Conv B	time (h)	GC Sel. (mol%)				Ratio 1/3	TON
					1-OMe + 3-OMe	VCH	OT	Olig.		
1	[BMMI][BF ₄]	100	92	1	81.8	0.2	15.1	2.9	8	2619
2	[BMMI][TF ₂ N]	100	89	1	84.0	0.2	13.7	2.1	9	2537

(a)- Reaction conditions Pd(OAc)₂ = 30 mg (0.134 mmol); PPh₃ = 105 mg (0.400 mmol); Ionic liquid (4 ml); MeOH = 15 ml (370 mmol); C₄H₆ = 20 g (370 mmol); T = 85 °C;

[0103] Excellent results were found for the 1,2,3-trialkylimidazolium ionic liquids regarding conversions and reaction rates (Cat. Ex. 1 and 2). Quantitative conversions were achieved after 1 h for the two solvents studied [BMMI][TF₂N] and [BMMI][BF₄]. Selectivity toward telomers are around 83 % and, again, there is a notable effect on the regioselectivity of the telomerization reaction, the ratio 1-OMe/3-OMe in excess of 8-9. It seems that the nature of the anion of the salts (between the hydrophobic Tf₂N⁻ salt and the hydrophilic BF₄⁻ salt) does not induce any notable difference in terms of activity and selectivity. Furthermore, at the end of these reactions, absolutely no palladium black was observed. A two-phase liquid-liquid system remains in the case of 1,2,3-trialkylimidazolium salts. The lower phase corresponds to the ionic liquid whereas the upper one is a mixture of products and unreacted methanol.

Catalysis examples 3 to 5

[0104] Catalysis examples 3 to 5 were run using Pd(OAc)₂ and water-soluble TPPMS as catalyst system. The results are shown in table 2.

Table 2:

Telomerization of 1,3-butadiene with methanol in the presence of Pd(OAc) ₂ /TPPMS ^(a)									
Cat. Ex.	Pd(OAc) ₂ (mmol)	Temp. (°C)	time (h)	Conv A	Conv B	GC Sel. (mol%)			TON
						1-OMe+3-OMe	VCH	Oligomers	
3	0.134	85	1	100	93	77.9	0.3	17.1	2769
4	0.028	85	5.75	85	80	77.7	0.8	20.9	11092
5	0.025	110	5.75	89	75	50.4	3.0	41.8	11953

(a)- Reaction conditions: TPPMS = 3 eq/Pd; [BMM]/[TF₂N] (4 ml); MeOH = 15 ml (370 mmol); C₄H₆ = 20 g (370 mmol);

[0105] The use of TPPMs lead to single phase system at 93% conversion (Cat. Ex. 3). Selectivity toward telomer is lower with TPPMS than with TPP, 77.9 against 84.0%. However with TPPMS the ratio 1-OMe/3-OMe is largely better, 13.7, The addition of 16%wt (10ml) of heptane to the solution obtained in Cat. Ex. 3 lead to clean separation of an ionic liquid phase from the product/MeOH/heptane phase.

Catalysis examples 6 to 8

[0106] Catalysis examples 6 to 8 were run in the presence of n-heptane using Pd(OAc)₂ and different phosphines. The palladium leaching into the organic phase was determined by microanalysis of the two phases. The results are shown in table 3.

Table 3:

Telomerization of 1,3-butadiene with methanol in the presence of n-heptane using Pd(OAc) ₂ and different phosphines ^(a)										
Cat. Ex.	P	Conv A	Conv B	GC Sel. (mol%)			Ratio 1/3	% Pd leaching	TON	
				1-OMe+3-OMe	VCH	OT				Oligo.
6	TPP	82	71	53.3		40.6	6.1	14.6	14.2	2127
7	TPPMS	74	66	70.3	0.6	14.1	15.0	13.1	1.9	1816
8	TPPDS	56	51	58.6	1.2	17.5	22.8	15.0	1.8	1373

(a): Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); Phosphine = 3 eq/Pd; [BMMI][TF₂N] (4 ml), MeOH = 75 ml (185 mmol); heptane = 10 ml; C₂H₆ = 20 g (370 mmol); t = 3 h; T = 65 °C.

(a)- Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); Phosphine = 3 eq/Pd; [BMMI][TF₂N] (4 ml); MeOH = 75 ml (185 mmol); heptane = 10 ml; C₄H₆ = 20 g (370 mmol); t = 3 h; T = 85 °C;

Catalysis examples 9 to 13

[0107] The product phase of catalysis example 7 was decanted and the palladium contained in the ionic liquid phase was reintroduced to the reactor with fresh reactants and co-solvent. Microanalysis of the organic phase at the end of each catalysis example 10 to 14 indicates 1-4% leaching of palladium to the organic phase. Slight changes in activity were observed with each cycle. At first, activities are actually higher (catalysis examples 10 to 12) perhaps as the initiation reactions (conversion of Pd(OAc)₂ to the active species) reach completion. Activity slowly degrades in catalysis examples 12 and 13, in part perhaps due to the mechanical difficulty of quantitatively recuperating the ionic liquid phase (drops of the liquid can remain in the schlenk tube used for decantation and/or syringe), palladium leaching, or to some palladium deactivation. In no case was there obvious evidence for the formation of palladium black. The results are shown in table 4.

Table 4:

Telomerization of 1,3-butadiene with methanol in the presence of n-heptane using recycled ionic liquid phase (a)								
Cat. Ex.	Conv A	Conv B	GC Sel. (mol%)				Ratio 1/3	TON
			1-OMe+3-OMe	VCH	OT	Oligo.		
9	74	66	70.3	0.6	14.1	15.0	13.1	1816
10	82	73	72.2	0.5	13.2	14.2	12.4	2001
11	89	81	72.4	0.4	15.9	11.3	15.4	2249
12	80	68	75.6	0.5	16.2	7.7	16.3	1907
13	70	63	78.8	0.9	17.3	3.1	18.6	1709

(a)- Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); TPPMS = 146 mg (0.401 mmol); [BMMI][TF₂N] (4 ml); MeOH = 7.5 ml (185 mmol); heptane = 10 ml; C₄H₆ = 20 g (370 mmol); T = 85 °C; t = 3 h.

Comparative Catalysis Examples 1 to 5

[0108] Comparative catalysis examples 1 to 5 were run using 1,3-dialkylimidazolium salts. The results are shown in table 5.

Table 5:

Telomerization of 1,3-butadiene with methanol using Pd(OAc) ₂ /PPh ₃ as a catalyst system in the presence of 1,3-dialkylimidazolium salts as ionic liquid ^(a)									
Comp. Cat. Ex.	Ionic Liquid	Conv A	Conv B	GC Sel. (mol%)				Ratio 1/3	TON
				1-OMe + 3-OMe	VCH	OT	Oligo.		
1	[BMI][TF ₂ N] (b)	10	7	62.0	18.4	3.5	16.1	7.8	241
2	[EMI][TF ₂ N] (b)	7	3	66.1	21.6	1.7	10.6	5.8	146
3	[EMI][TF ₂ N] (c)	16	6	27.5	44.7	0.6	27.1	6.5	271
4	[BMI][BF ₄] (c)	15	-1	49.6	33.9	1.2	15.4	5.1	165
5	[EMI][PF ₆] (d)	13	2	38.0	49.8	8.2	4.0	7	184

(a)- Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); PPh₃ = 105 mg (0.400 mmol); MeOH = 145 ml (370 mmol); C₄H₆ = 20 g (370 mmol); T = 85 °C; t = 22 h.

(b)- 1 ml of ionic liquid;

(c)- 4 ml of ionic liquid;

(d)- Ionic liquids purchased from Aldrich (97 % pure, white solid, equivalent of 1 ml of ionic liquid)

Gleitzeitantrag / Korrektur

(bitte Nichtzutreffendes durchstreichen)

Name Karin Henzold		
Gleitzeittagnahme	am	
Vertretung		
Korrektur	von	bis
am: 26. Mai 2004	12.06 Uhr	13.21 Uhr
am:		
Korrekturgrund: <input type="radio"/> Nichtstempeln <input type="radio"/> Dienstgang _____ <input type="radio"/> Arztbesuch (Beleg beifügen) <input type="radio"/> Sonstiges _____		
Datum 23.06.2004	Unterschrift des Antragssteller	
genehmigt: (nur bei Gleitzeittagnahme Unterschrift einholen)		

[0109] Conversions were extremely low. There was, however, no obvious formation of palladium black: systems, at the end of the reaction, appear as homogeneous quite colorless liquids. The « palladium-phosphine » catalyst supposed to be formed *in situ* certainly suffered of some modifications and so deactivation. The possible contamination of halide impurities from the ionic liquid was first evoked. Indeed, synthesis of some ionic liquids is based on the use of chloride intermediates, potentially present in the remaining salts. However, this hypothesis can be totally excluded to explain this phenomenon. Indeed the halide contents of ionic liquids were always under the detection limit (50-250 ppm) which constitutes would be too little for total contamination of the catalyst. Moreover, this behavior is observed with both commercial salts (Comp. Cat. Ex. 5) and ionic liquids synthesized in the laboratory which exclude any questions concerning purity of salts used in those experiments.

Comparative Catalysis Examples 6 to 9

[0110] Comparative catalysis examples 6 to 9 were run using 1,3-dialkylimidazolium salts and different phosphine/palladium ratios in order to determine their influence on the conversion and selectivity. The results are shown in table 6.

Table 6:

Telomerization of 1,3-butadiene with methanol using Pd(OAc) ₂ /PPh ₃ with different Pd/phosphine ratios as a catalyst system in the presence of 1,3-dialkylimidazolium salts as ionic liquid ^(a)									
Comp. Cat. Ex.	P/Pd ratio	Conv A	Conv B	GC Sel. (mol%)				Ratio 1/3	TON
				1-OMe + 3-OMe	VCH	OT	Oligo.		
6	3	11	1	56.2	32.9	1.7	9.2	5.9	166
7	4	11	5	72.9	27.1	-	-	5.9	228
8	10	26	19	73.0	9.9	-	17.1	6.5	593
9	20	30	23	71.0	12.7	2.3	14.0	6.5	745

(a)- Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); [EMI][TF₂N] (1 ml); MeOH = 15 ml (370 mmol); C₄H₆ = 20 g (370 mmol); T = 85 °C; t = 22 h.

[0111] Again, even with a large excess of PPh₃ performances of the catalytic system remain very low. With 20 equivalents of phosphine per palladium, conversion does not exceed 26 % (Comp. Cat. Ex. 9).

Catalysis examples 14 and 15

[0112] Catalysis examples 14 to 15 for telomerizing 1,3-butadiene with glycol in the presence of n-heptane were run using Pd(OAc)₂/TPPMS as the catalyst system, Table 7 shows the results.

Table 7:

Telomerization of 1,3-butadiene with Glycol in the presence of n-heptane using Pd(OAc) ₂ /TPPMS as a catalyst system ^(a)									
Cat. Exp.	Conv A	Conv B	GC Sel. (mol%)					Ratio 1/3	TON
			1-OGly + 3-OGly	VCH	OT	Oligo.	(1+3)-OGly ²		
14 ^(b)	96	87	67.6	5.2	4.2	1.7	21.3	24	2767
15 ^(c)	93	81	79.9	-	6.9	-	13.2	26	2482

(a)- Reaction conditions: Pd(OAc)₂ = 30 mg (0.134 mmol); TPPMS = 0.146 g (0.401 mmol); Glycol = 10.5 ml (185 mmol); [BMMI][TF₂N] = 4 ml; C₄H₆ = 20 g (370 mmol); T = 85 °C; t = 45 mn;

(b)- heptane 10 ml

(c)- heptane 30 ml.

Catalysis examples 16 and 17

[0113] Catalysis example 16 for telomerizing 1,3-butadiene with water were run using $\text{Pd}(\text{OAc})_2/\text{TPPMS}$ as the catalyst system. Table 8 shows the results.

Table 8:

Telomerization of 1,3-butadiene with water using $\text{Pd}(\text{OAc})_2/\text{TPPMS}$ as a catalyst system ^(a)										
Ref. ML	Amine	Heptane (ml)	Conv A	Conv B	% GC. (mol)				Ratio (1/3)	TON
					Octadienols	VCH	OT	Oligo.		
121 (b)	NEt_3 (d)	-	95	95	74.0	-	18.8	7.2	17	1164
133 (c)	NEt_3 (d)	30	78	70	67.9	<0.1	32.1	<0.1	18	961

(a)- Reaction conditions: $\text{Pd}(\text{OAc})_2 = 0.050$ g (0.223 mmol); TPPMS = 324 mg (0.892 mmol); $[\text{BMMI}][\text{BF}_4] = 4$ ml; $\text{C}_4\text{H}_6 = 15$ g (278 mmol); $\text{H}_2\text{O} = 5$ g (278 mmol); $\text{P}_{\text{CO}_2} = 5$ bar; $T = 85^\circ\text{C}$;

(b)- $t = 3$ h;

(c)- $t = 5$ h;

(d)- $\text{NEt}_3 = 50$ eq/Pd;

Catalysis examples 18 and 21

[0114] Catalysis example 21 for dimerization - oligomerization of 1,3-butadiene were run using $\text{Pd}(\text{OAc})_2$ as the catalyst system. Table 9 shows the results.

Table 9:

Oligomerization of 1,3-butadiene using $\text{Pd}(\text{OAc})_2$ as a catalyst system ^(a)								
Cat. Ex.	Ionic Liquid	Conv A	Conv B	% GC. (mol)				TON
				VCH	OT	Butadiene trimers	Olig.	
18	$[\text{EMI}][\text{TF}_2\text{N}]$	41	34	29.9	10.6	39.2	20.3	463
19	$[\text{BMMI}][\text{BF}_4]$	9	8	52.4	9.6	8.6	29.4	106
20	$[\text{BMMI}][\text{PF}_6]$	38	33	34.7	8.7	28.3	28.3	520
21	$[\text{BMMI}][\text{TF}_2\text{N}]$	70	67	70.9	6.3	10.7	12.1	727

(a)- Reaction conditions: $\text{Pd}(\text{OAc})_2 = 0.050$ g (0.223 mmol); Ionic liquids = 4 ml; $\text{C}_4\text{H}_6 = 15$ g (278 mmol); $\text{H}_2\text{O} = 5$ g (278 mmol); $\text{P}_{\text{CO}_2} = 5$ bar; $T = 85^\circ\text{C}$; $t = 22$ h;

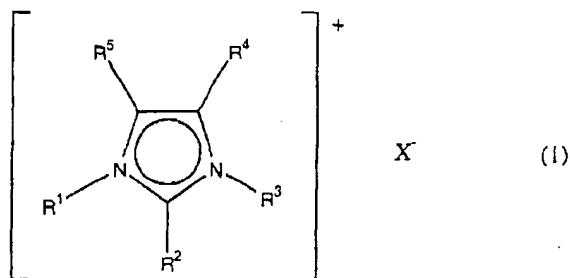
[0115] In terms of butadiene conversion, one will note that the use of $\text{BMMI}+\text{TF}_2\text{N}$ - increase considerably the conversion.

[0116] The invention will now be described in greater detail with the aid of embodiments given as non-limiting examples.

Claims

1. Use of 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-, tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with sulfonated or carboxylated triesters of phosphorous acid as anion, as solvent.

2. A use according to claim 1 wherein the 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts are of the following formula (1)



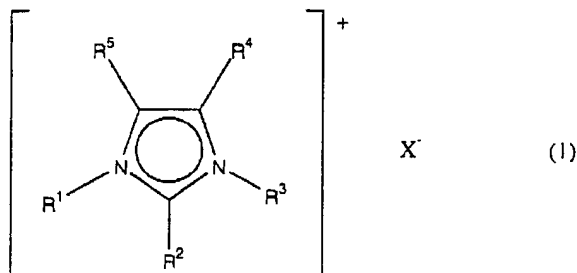
wherein R¹ and R³ are the same or different and are each selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms, and a tri(C1-C10) alkylsilyl group, R² is selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms and a halogen atom, R⁴ and R⁵ are the same or different and are each selected from the group consisting of hydrogen, a chiral or achiral alkyl group having up to 10, preferably up to 6 carbon atoms, a chiral or achiral aryl group of 6 to 10 carbon atoms, a chiral or achiral tri(C1-C10)alkylsilyl group, and a halogen atom, and X⁻ represents an anion.

3. A use according to the claims 1 or 2, wherein X⁻ is selected from anions of the group consisting of fluoride, chloride, bromide, iodide, hexafluorophosphate, hexafluoroantimonate, hexafluoroarsenate, fluorosulfonate, tetrafluoroborate, bisperfluoro (C1-C10)alkylsulfonyl amides, perfluoro(C1-C10)alkyl sulfonates, dichlorocuprate, tetrachloroborate, tetrachloroaluminate, heptachlorodialuminate (Al₂Cl₇⁻), trichlorozincate, and anions of sulfonated or carboxylated (alkyl and/or aryl)-phosphines or phosphites.
4. A use according to any of the claims 1 to 3, wherein 1,2,3-tri(C1-C10)alkyl-imidazolium salts are used as a solvent.
5. A use according to any of the claims 1 to 4, wherein a 1-n-butyl-2,3-dimethylimidazolium salt is used as a solvent.
6. A use according to any of the claims 1 to 5, wherein the solvent is a solvent in organic reactions.
7. A use according to claim 6, wherein the organic reaction is selected from the group consisting of the catalytic conversion of olefins, in particular selected from the telomerisation of conjugated dienes, the dimerisation of olefins, the oligomerisation of olefins, the polymerization of olefins, the alkylation of olefins, the hydrogenation of olefins, the olefin metathesis, the hydroformylation of olefins, the ring-closing metathesis of olefins, the ring-opening metathesis polymerisation of olefins, the symmetric or asymmetric epoxidation of olefins (including heteroatom substituted olefins) and the cyclopropanation of olefins, the condensation reaction, the hydrogenation reaction, the isomerization reaction, the Suzuki cross-coupling reactions, the amination reaction, the partial oxidation of alkanes, the kinetic resolution of racemic mixtures, the hydrogenation of imines, the hydrogenation of ketones, the transfer hydrogenation and the hydroxylation of aromatic compounds.
8. A use of 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, with the exception of 1,2,3,4,5-pentamethyl imidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium salts with sulfonated or carboxylated triesters of phosphorous acid as anion, preferably according to any of the claims 1 to 7 as a catalyst or catalyst component.
9. A use of 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts, with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium-, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with a sulfonated or carboxylated triester of phosphorous acid as anion, preferably according to any of the claims 1 to 8 in a two-phase catalytic reaction.
10. Use of 1,2,3-substituted imidazolium salts, 1,2,3,4-substituted imidazolium salts or 1,2,3,4,5-substituted imidazolium salts with a metal-containing compound, preferably of transition metal in an organic reaction selected from the group consisting of the catalytic conversion of olefins, in particular selected from the telomerisation of conju-

gated dienes, the dimerisation of olefins, the oligomerisation of olefins, the polymerization of olefins, the alkylation of olefins, the hydrogenation of olefins, the olefin metathesis, the hydroformylation of olefins, the ring-closing metathesis of olefins, the ring-opening metathesis polymerisation of olefins, the symmetric or asymmetric epoxidation of olefins (including heteroatom substituted olefins) and the cyclopropanation of olefins, the condensation reaction, the hydrogenation reaction, the isomerization reaction, the Suzuki cross-coupling reactions, the amination reaction, the partial oxidation of alkanes, the kinetic resolution of racemic mixtures, the hydrogenation of imines, the hydrogenation of ketones, the transfer hydrogenation and the hydroxylation of aromatic organic compounds.

11. Use according to claim 10, wherein the salts are used as a solvent.

12. Imidazolium salts of the following formula (I) :



wherein R^1 and R^3 are the same or different and are each selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms, and a tri(C1-C6)alkylsilyl group, R^2 is selected from the group consisting of an alkyl group having up to 10, preferably up to 6 carbon atoms, an aryl group of 6 to 10 carbon atoms and a halogen atom, R^4 and R^5 are the same or different and are each selected from the group consisting of hydrogen, a chiral or achiral alkyl group having up to 10, preferably up to 6 carbon atoms, a chiral or achiral aryl group of 6 to 10 carbon atoms, a chiral or achiral tri(C1-C6)alkylsilyl group, and a halogen atom, and X^- represents an anion,

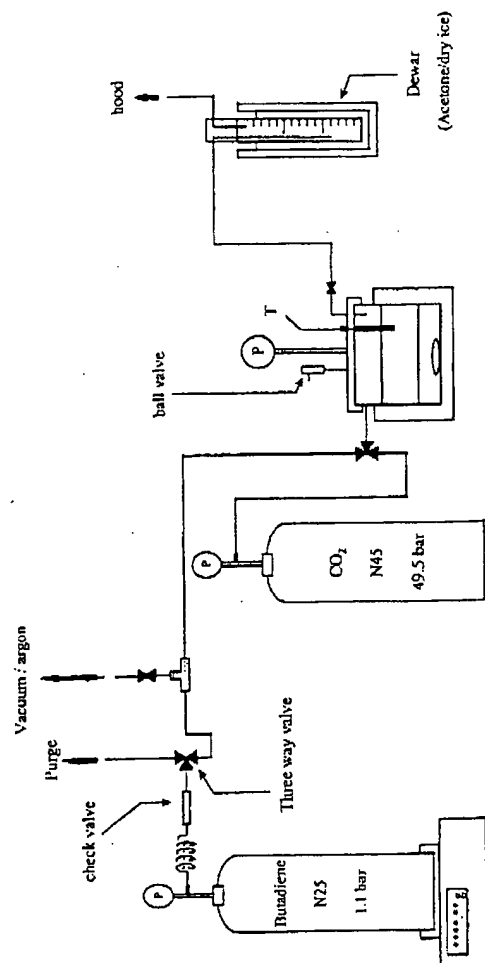
with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts of sulfonated or carboxylated triesters of phosphorous acid, 1,2,3,4,5-pentamethylimidazolium iodide, 1,2,3-trimethylimidazolium bromide, 1,2,3-trimethylimidazolium iodide, 1,2-dimethyl-3-ethylimidazolium bromide, 1,2-dimethyl-3-ethylimidazolium chloride, 1,2-dimethyl-3-butylimidazolium fluoride, 1-butyl-2,3-dimethylimidazolium salt of 2,2'-(2,5-cyclohexadiene-1,4-ylidene)bis[propanedinitril], 1,3-dimethyl-2,4,5-trichloroimidazolium tetrafluoroborate, 1,3-dimethyl-2,4,5-tribromoimidazolium tetrafluoroborate, 1,3-dimethyl-2,4,5-tribromoimidazolium bromide.

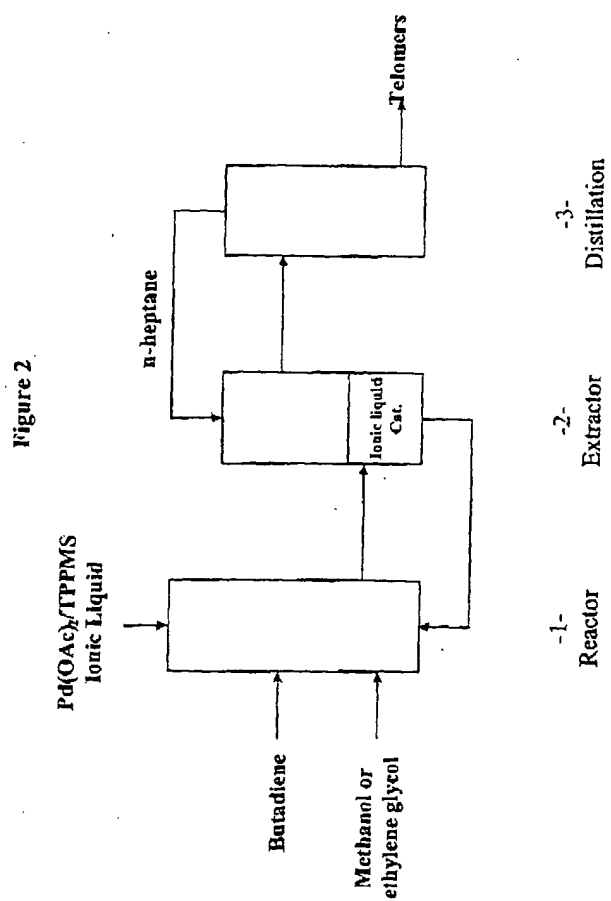
13. An imidazolium salt according to claim 12 selected from 1-n-butyl-2,3-dimethylimidazolium bistrifluoro(C1-C10)alkylsulfonylamide, 1-n-butyl-2,3-dimethylimidazolium tetrafluoroborate or 1-n-butyl-2,3-dimethylimidazolium hexafluorophosphate.

14. Composition comprising a 1,2,3- or 1,2,3,4- or 1,2,3,4,5- substituted imidazolium salt as solvent, a metal compound, and a phosphorous-containing compound.

15. Composition comprising a transition metal and a 1,2,3- or 1,2,3,4- or 1,2,3,4,5-substituted imidazolium salt, with the exception of 1,2,3,4,5-pentamethylimidazolium-, 1,2,3,5-tetramethyl-4H-imidazolium-, 1,2,3,4-tetramethyl-5H-imidazolium, and 1-trimethylsilyl-2,3,5-trimethyl-4H-imidazolium-salts with sulfonated or carboxylated triesters of phosphorous acid as anion.

Figure 1







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PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

EP 00 40 3008

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.CI.7)
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-/-			TECHNICAL FIELDS SEARCHED (Int.CI.7)
			C07D C07F C07C C08F
INCOMPLETE SEARCH			
<p>The Search Division considers that the present application, or one or more of its claims, does/does not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.</p> <p>Claims searched completely :</p> <p>Claims searched incompletely :</p> <p>Claims not searched :</p> <p>Reason for the limitation of the search:</p> <p>see sheet C</p>			
Place of search		Date of completion of the search	Examiner
THE HAGUE		20 June 2001	Van Bijlen, H
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			

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INCOMPLETE SEARCH
SHEET C

Application Number
EP 00 40 3008

Claim(s) searched completely:
1-11, 13-15

Claim(s) searched incompletely:
12

Reason for the limitation of the search:

The initial phase of the search for claim 12 (imidazolium salts "per se") revealed a very large number of documents relevant to the issue of novelty of compounds of general formula (I). So many documents were retrieved that it is impossible to determine which parts of the claim 12 may be said to define subject-matter for which protection might legitimately be sought (Article 84 EPC). For these reasons, a meaningful search over the whole breadth of claim 12 is impossible. Also a restricted search, in line with the preparation examples for compounds of formula (I) wherein R1, R2 and R3 are alkyl yielded a very large number of documents relevant to the issue of novelty. However with respect to the preparation examples of the present application the search can be considered complete.



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Application Number
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
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Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 00 40 3008

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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20-06-2001

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